Boeing Technology
Phantom Works

FAA HUMS Technology Development Plan Study

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Rotorcraft Damage Tolerance and Health and Usage Monitoring Systems Research Review Meeting

NASA Ames

December 9, 2004

BOEING PROPRIETARY

Background

- **Federal Aviation Authority (FAA) has contracted The Boeing Company for a study effort to:**
  - **determine current state-of-the-art and state-of-practice in rotorcraft Health and Monitoring Systems (HUMS)**
  - **identify the required capabilities and enabling technologies and projects**

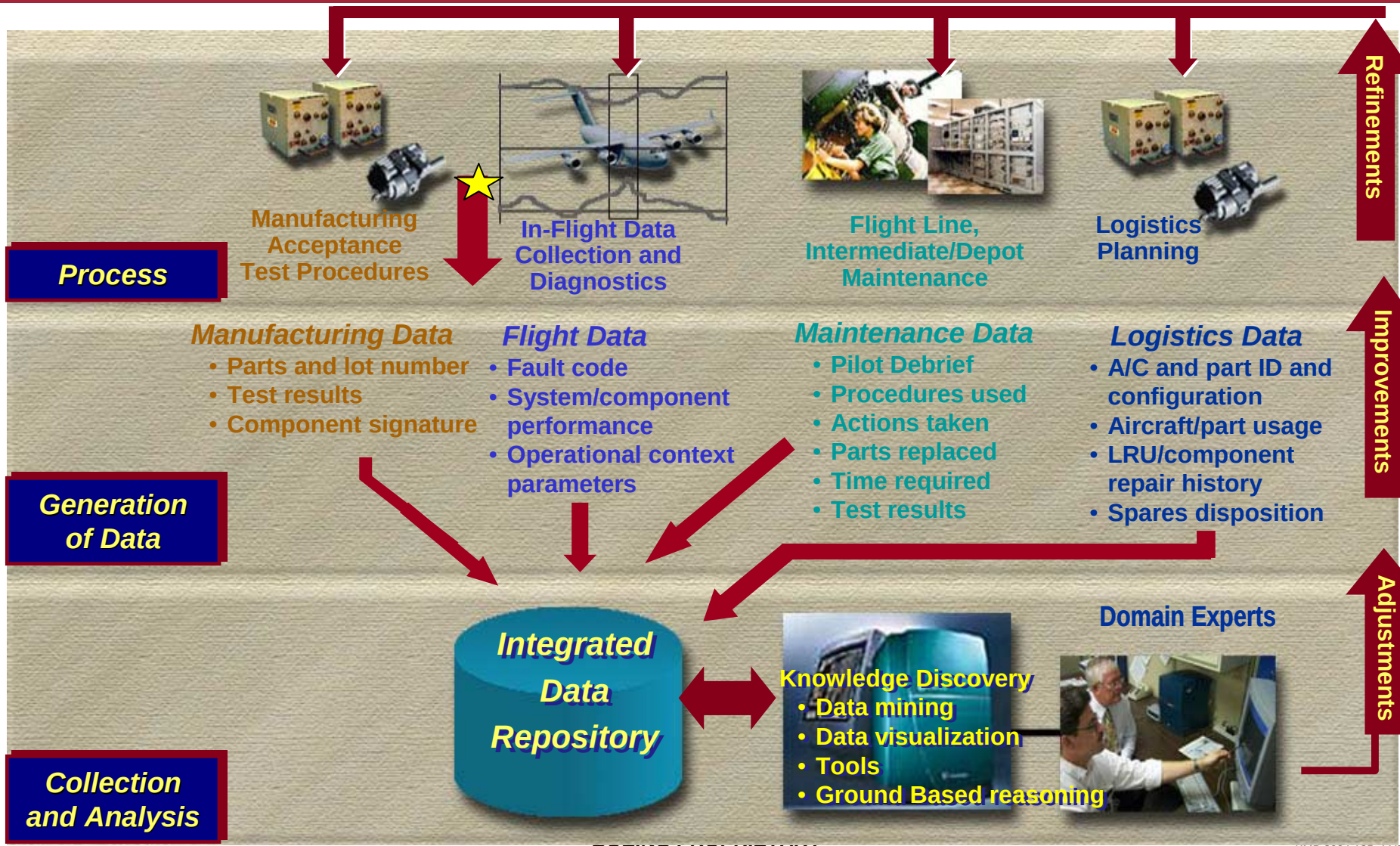
Goal

- **To provide FAA with information in regards to HUMS technology to be used in FAA Health and Usage Monitoring Technology Research and Development Planning**

Study Report

- **State of current HUMS**
- **State of current research**
- **Required capabilities**
- **Gap analysis**
- **Proposed projects**
- **Roadmap**

Health Management Development Process and Certification



Scope

- **Ground System / Station**
- **Structural Usage Monitoring**
- **Transmission Diagnostics**
- **Rotor Track and Balance**

Customers' Requirements

- **Functional**
  - Improved Safety
  - Improved Maintainability
  - Improved Availability
- **Non-Functional**
  - Certification

Certification

Installation, Credit Validation, Continued Airworthiness

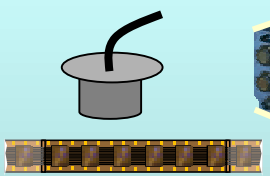
- **Data and technical information**
- **Guidelines and procedures**
- **Tools for affordable certification**

Customers' Requirements and IVHM Technology Elements

Improved Safety | **Improved Maintainability** | **Enhanced Availability** | **Affordable Certification**

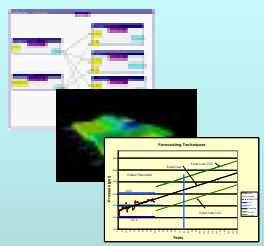
Effective Prognostics | **Effective Diagnostics** | **Standard Architecture**

Sensors,

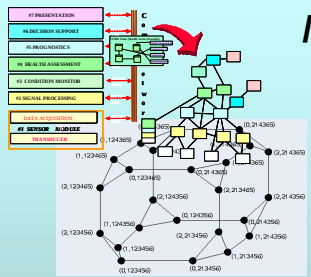


Data Acquisition System

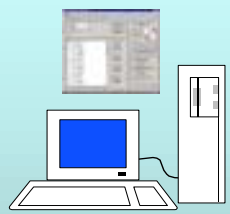
Algorithms/ Methodology



Architecture Infrastructure



Data Management /Tools/Models



Human Machine Interface

Integration Technologies

Installation | **Credit Validation**

Continued Airworthiness

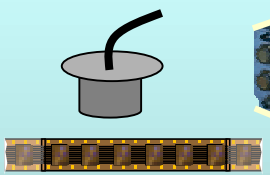
FAA Requirements and IVHM Technology Elements

New HUMS AC

Affordable Certification

Technical Data **New Material** **Tools**

Sensors,



Data Acquisition System

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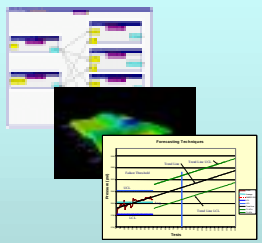
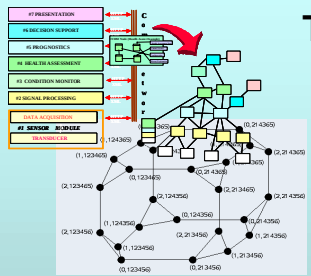
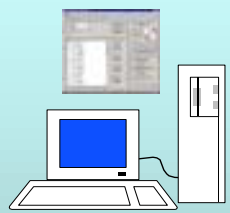


Architecture Infrastructure



Data Management Tools/Models



Integration Technologies

Human Machine Interface

Installation **Credit Validation**

Continued Airworthiness

Prioritization

- **Objective: Identify and rank the technologies that meet the FAA needs for safety and certification of HUMS for Maintenance Credit**
- **How:**
  - Quality Function Deployment
  - Mapped the top level requirements to HUMS capabilities
  - Identified enabling technologies for each capability
  - Ranked the technology

Technology Ranking

Legend Key:

Value	Definition
5	Major Contribution, Paradigm Shift
4	Substantial Contribution, Enabling Technology
3	Supportive and Essential
2	Supportive
1	Minor Contribution
0	No Contribution

HUMS Prioritization Table

			Importance per Customer's Requirements 0 (low) to 5 (high)				
item #	Capabilities	Capability Details	Enhanced Safety	Reduced Maintenance	Improved Readiness		Weighted Priority - FAA
		Total:	56.5	59	52.5		
1	Structural Usage Monitoring						
1a		Safe Life Methodolgy/Regime Based	3.5	3.5	3		3.35
1b		Safe Life Methodology/Load Based	4.5	4	3.5		4.1
1c		Damage Tolerance/Load Based	4	5	3.5		4.05
1d		Damage Tolerance/Regime Based	3.5	3	3		3.25
1e		Exceedance Montoring	3	2	2.5		2.65
2	Drivetrain Health Monitoring						
3	Rotor Tuning and Health Monitoring System						
4	Ground System						

HUMS Prioritization (Cont.)

			Technology Element Ranking By Capability Detail - 0 to 5 level of importance							
item #	Capabilities	Capability Details	Sensor Technology	Data Acquisition	Models and Tools	Algorithms/ Methodology	Software Architecture	Database/ Data mining	Integration Technology	Human Machine Interface
1	Structural Usage Monitoring									
1a		Safe Life Methodolgy/Regime Based	1	2	2	3	2	4	1	0
1b		Safe Life Methodology/Load Based	5	3	2	3	2	4.5	1	0
1c		Damage Tolerance/Load Based	5	3	4	4	2	4.5	1	0
1d		Damage Tolerance/Regime Based	1	2	4	4	3	4	1	0
1e		Exceedance Montoring	2	2	0	2	2	3	1	0
2	Drivetrain Health Monitoring									
3	Rotor Tuning and Health Monitoring System									
4	Ground System									

HUMS Prioritization (Cont.)

		Technology Element Weighted Ranking By Capability Detail - Weighting per Customer (FAA					
Capabilities	Capability Details	Sensor Technology	Data Acquisition	Models and Tools	Algorithms/ Methodology	Software Architecture	Database/ Data mining
Structural Usage Monitoring							
	Safe Life Methodolgy/Regime Based	3.35	6.7	6.7	10.05	6.7	13.4
	Safe Life Methodology/Load Based	20.5	12.3	8.2	12.3	8.2	18.45
	Damage Tolerance/Load Based	20.25	12.15	16.2	16.2	8.1	18.225
	Damage Tolerance/Regime Based	3.25	6.5	13	13	9.75	13
	Exceedance Montoring	5.3	5.3	0	5.3	5.3	7.95
Drivetrain Health Monitoring							
Rotor Tuning and Health Monitoring System							
Ground System							
	Total:	116.50	82.00	132.60	172.65	162.65	203.63
	5 x Normalized Total:	**2.9**	**2.0**	**3.3**	**4.2**	**4.0**	**5.0**

Project Definitions

- **Ground System**
- **Structural Usage Monitoring**
- **Drive System Diagnostics**
- **Rotor Track and Balance**

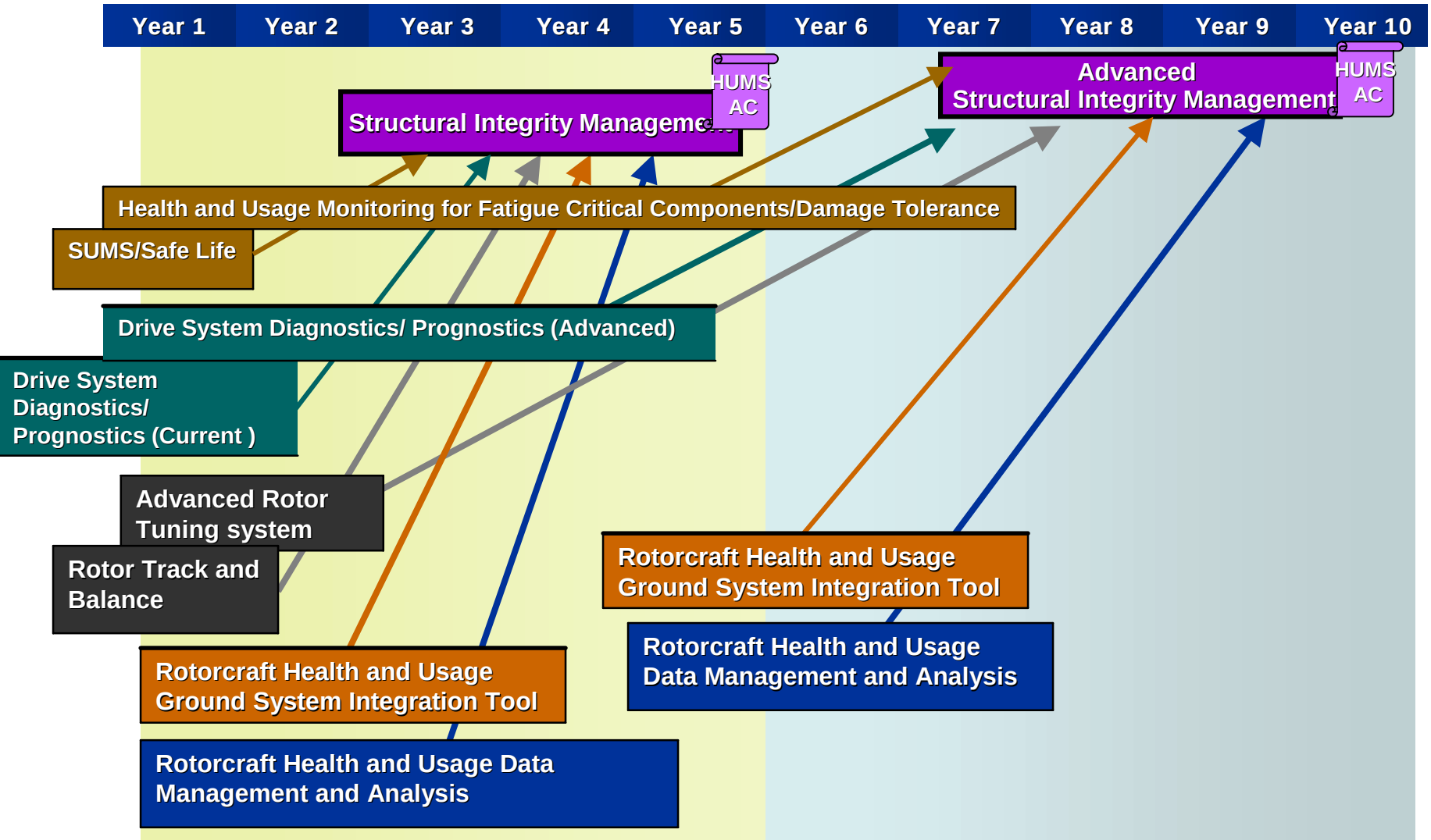
Roadmap

- **Short Term (1 - 5 years)**
  - Infrastructure development
  - Integration of existing capabilities
  - Development of new capabilities
- **Deliverables**
  - (Demonstration of an integrated solution)
  - Updated AC (new material and technical data)
  - Tools for certification

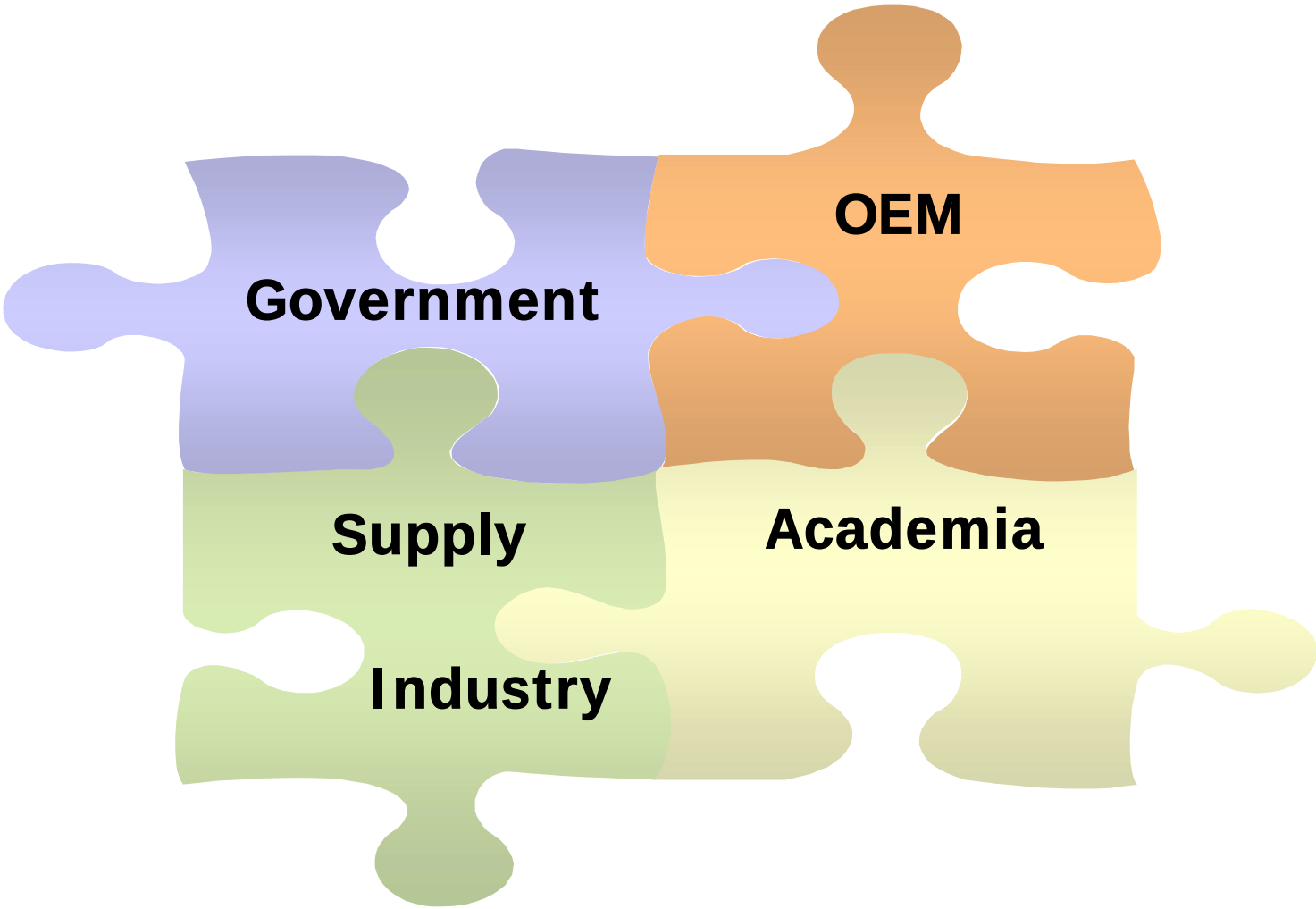
Roadmap (Cont.)

- **Long Term (5 - 10 Years)**
  - Infrastructure upgrade
  - Integration of advanced capabilities
- **Deliverables**
  - Demonstration of an advanced integrated solution
  - Updated FAA HUMS AC (new material, technical data)

FAA HUMS Capability Roadmap



Collaboration



Summary/Conclusion

- **Summary**
  - The enabling HUMS technologies are identified
  - A roadmap is developed
  - Collaboration is shown
  - Exit criteria and output for projects are identified
- **Conclusion**
  - A tightly orchestrated, collaborative effort is required to mature the HUMS technology for qualification and Certification for Maintenance Credit